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GIFFORD PINCHOT, Forester.

INSTRUCTIONS TO ENGINEERS OF TIMBER TESTS.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Forest Service,
Washington, D. C., February 13, 1906.

Sir: I have the honor to transmit herewith a manuscript entitled "Instructions to Engineers of Timber Tests," by W. Kendrick Hatt, Civil Engineer, Forest Service, and to recommend its publication as Circular 38 of the Forest Service.

The text figures accompanying the manuscript are necessary for its proper illustration.

Very respectfully,

Gifford Pinchot,
Forester.

Hon. James Wilson,
Secretary of Agriculture.

CONTENTS.

INSTRUCTIONS TO ENGINEERS OF TIMBER TESTS.

INTRODUCTION.

This manual presents detailed instructions for testing timber and recording the data obtained, which are standard at the date of publication. These instructions are to be followed literally, as far as possible, in all the timber tests made by the Forest Service.

The general plan of these timber tests is to determine the relation between the physical characteristics of wood and the mechanical properties, and the effect of various technological operations upon them; to establish authoritative data for design; to collect data for the improvement of specifications for market products; to study the best methods of testing; and to determine what species may be used as substitutes for those now becoming scarce. The programme as laid out at present is as follows:

TESTS TO DETERMINE PROPERTIES OF STRUCTURAL TIMBER.

Series I.—Tests of the mechanical and physical properties of timber in forms found on the market. The material will be of actual sizes and grades in commercial use. The purpose is to determine moduli for design; to determine the value of woods now considered inferior; to determine the liability to knots and the equivalent reducing factors; to arrange a table of rules of inspection and grading; and partly to compare the properties of species from different regions.

TESTS TO DETERMINE THE EFFECT OF VARIATIONS IN THE CONDITIONS.

Series II.—Effect of rate of application of load, including impact tests.

Series III.—Effect of moisture.

STUDIES OF THE EFFECT OF TECHNOLOGICAL PROCESSES.

Series IV.—Preservatives.

Series V.—Methods of seasoning.

GENERAL DIRECTIONS.

CARE OF APPARATUS.

The engineer of tests is held responsible for the condition of the apparatus in his care. He should keep an inventory of apparatus in the laboratory, and note breakage, losses, or transfers. In general there should be provided a proper receptacle for the apparatus in the laboratory, and after the testing work is over, all apparatus should be carefully put away and protected from rust.

THE TESTING MACHINE.

The gears should be oiled[a] about once a week. It is very necessary that the screws of both the Olsen and Riehlé machines should be kept clean. These screws should be wiped clear of grit once a week, and in case they become gummed, the gummed oil should be eaten away with gasoline and the screws reoiled. Care should be taken in operating the levers of the testing machine not to throw in the gears while in motion. The bearings of the knife edges should be kept clean and examined at intervals. If the machine has a cross table it is particularly important that clearance should exist between the floor of the laboratory and all parts of this table. The wedges and other exposed metal surfaces of the machine should be kept from rusting by the application of slush.

CALIBRATION OF APPARATUS.

The testing machines, as a rule, are calibrated to a portion of their capacity before leaving the factory. The delicacy of the levers is also verified by determining the number of pounds which will cause the beam to move between the stops while a load of 1,000 pounds rests on the platform. The usual requirement is that 10 pounds shall accomplish this movement. The machines used in testing timber should be calibrated by the use of a standard bar and an extensometer. This standard bar is of nickel steel, about 1 inch in diameter, with an elastic limit of about 85,000 pounds per square inch. The machine is calibrated by pulling this bar nearly up to the elastic limit and noting the readings of the extensometer. The deflectometers should be calibrated as often as necessary to determine their accuracy.

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[a] The following directions are given by the manufacturers of the Olsen testing machine:

Oil the four pulling screws well at least once a day when in constant use, directly on the threads or in the feather-way of same. Oil central vertical shaft once a week, through an oil hole in the horizontal bevel wheel inside of the drum, or base, of the machine. Oil, once a day, the horizontal shaft for large spur wheel by pouring oil in groove reached from the outside, through the spokes of the spur wheel; oil the countershaft and loose pulleys once or twice a day. Oil the main bearings for the four pulling screws well, once a week, by pouring oil in the holes on side of top of drum.

OBSERVATIONS.

Observers should remember that the methods of observation used in Government timber tests should be above reproach, and that it is worth while to go somewhat beyond the immediate requirements of accuracy in order to leave no reasonable ground for criticism. At the same time, the question of economy of time must be considered, and to this end all useless refinements of observation should be discarded. The principle that governs may be formulated thus: *Methods of observation and calculation should be of a degree of accuracy suited to the character of the material under test;* and the degree of accuracy of the various kinds of measurements should be the same. A physicist, working with small quantities of uniform material, uses very refined methods of measurement which would not be necessary or suitable for the engineer in testing large beams of wood. A safe principle to follow in tests under the head of Series I is that errors of observation and calculation of less than 1 per cent may be disregarded. This means, for instance, that if the modulus of elasticity is determined from a bending test upon a beam that deflects 1 inch, the deflection at which this modulus is calculated should be accurate to one one-hundredth of an inch, and that the quotation of the calculated value of this modulus should be given to that degree of accuracy. Thus, the results obtained from tests under Series I should be quoted only to three significant figures. The modulus of elasticity, for instance, would read 1,120,000; fiber stress, 5,280, etc. The quotation of these values will thus, in many cases, be to a greater degree of accuracy than 1 per cent, but the rule may be allowed to stand. The observer will probably be surprised should he calculate the degree of accuracy of the various steps in the process of testing timber. He will find that many observations are made unnecessarily refined and that others are too rough.

Another rule which the observer and recorder should have in mind is that the notes should be in such condition as to enable an individual not present at the tests to determine all the essential facts which occurred. Almost all the facts required are asked for on the adopted forms. In describing the specimens under test and the method of failure, special care should be taken that the cause and position of the first indication of failure is given. For example, it is not enough to say that the beam failed in tension and compression. The record should be made that the beam failed, for example, in tension at a knot, so and so far from the center. This note should be made beside the load at which the failure occurred. Load-deformation curves should be drawn for the various tests.

The calculations may be made with a slide rule or a four-place table of logarithms. In bending tests the fiber stress should be calculated at the elastic limit and rupture, not only at the center of the beam, but

at the point of first failure. The load should include the weight of the beam. Carbon copies of all data should be taken at the time of test.

All calculations should be checked before the engineer's report is sent to the central office. It will be necessary to send also a copy of the diagrams from which the moduli were calculated. Specific directions for the record and calculation of individual tests will follow.

RESPONSIBILITY.

The engineer of tests in charge of a particular station is responsible for the accuracy of the results obtained, both as to observation and calculation. He is not responsible for the methods of test selected, but he should advise the central office of any improvements in any part of the work which may seem advisable to him as the result of his experience. He is also responsible for the progress of the work. He should bear in mind that the expense of salaries for this work is rather heavy, and that the work should be pushed as rapidly as is consistent with accuracy. The engineer in charge is responsible for the care of the equipment used in the tests. He is not ordinarily charged with the duty of selecting the material to be tested. This material is selected in conjunction with the representatives of the Forest Service. The engineer, by making abstracts of data, should keep track of the general character of the results obtained, so that any mistakes of selection or in methods pursued may be detected before the investigation proceeds too far.

ASSISTANTS.

The engineer of tests is provided with sufficient assistants to carry on the work most economically. The number and character of these assistants will depend upon the problem in hand. In testing large beams, for instance, which calls for considerable manual work, the most economical arrangement would involve a supply of skilled or unskilled labor, depending upon the facilities for power. The operations of the laboratory should be so planned that the different individuals may be kept working to the best advantage. A high-salaried, skilled man should not waste his time in doing the work of a common laborer.

WORKING PLANS.

Before any study is begun a working plan must be submitted to the central office and authorized. Such a working plan will include: (1) A statement of the problem; (2) a summary of present knowledge or reference to other investigations along the same line; (3) a list of material upon which tests are to be made; (4) a list of kinds of tests; (5) a detailed working outline of operations arranged according to series.

REPORTS.

Monthly reports stating the number of tests of various kinds made on the different studies and other work accomplished, together, when possible, with tentative conclusions drawn from the results, will be sent to the central office. At the completion of each study the engineer in charge is expected to prepare and submit to the central office a complete report on the work covered. It is the policy of the Forest Service to publish reports of general interest.

RECORDS.

The records of a station will be as follows:

GENERAL RECORDS.

A series of records will be kept in book form, consisting of:

(*a*) A diary, to contain a record of mechanical tests and moisture determinations and of individual work performed at the laboratory, together with other items of sufficient importance to justify a record.

(*b*) An expense account.

(*c*) Prints from photographic negatives.

RECORDS OF TESTS.

A file of running logs of tests and summaries of tests will be kept, consisting of:

(*a*) Descriptions of all sticks received at the laboratory.

(*b*) The running logs of all mechanical tests.

The records (*a*) and (*b*) should be filed in the same drawer. The logs should be filed in front of a guide card which indicates each stick number. The sticks should be numbered consecutively. Another arrangement would be one file drawer which would contain running logs derived from one kind of test, for instance, impact, static, or abrasion.

(*c*) Moisture determinations, which should be filed separately from the running logs and given consecutive numbers. These numbers are in a series independent of the series of laboratory numbers indicating the mechanical tests.

(*d*) A record of laboratory numbers, giving information concerning the series, study, kind of test, etc., to which each laboratory number refers.

(*e*) Summary sheets, giving the factors derived from running logs in the case of individual tests. The tests on any one summary sheet represent a natural group of data, the average of which indicates something with reference to the study under progress. These summary sheets are to be filed horizontally in drawers.

CARD INDEXES.

Card indexes, enabling the engineer quickly to find any particular record, should be kept as follows:

(*a*) Stick number index, giving species, shipment, kind of test made upon the stick, kind and size of specimen for each minor test, laboratory numbers, number of mechanical tests, moisture determinations, and photographs made of beams or specimens from beam.

(*b*) Shipment index, giving a record of shipment numbers, with information concerning the market or source of supply, species, locality of growth, nominal size of sticks, date of cutting, transportation, and stick numbers of any shipment.

(*c*) Study index, giving object, stick numbers, and summary tables for each study.

(*d*) Summary index, numbered, stating study involved, whether general or detail, and its disposition. Reference should be made to any accompanying table or diagram.

(*e*) An inventory, giving a full history of all nonexpendable material sent to or purchased for the laboratory.

(*f*) A negative index file in consecutive numbers, giving complete information of photographic negatives and record of their disposition.

Uniform blanks and cards for the above station records will be furnished from the central office.

PREPARATION OF MATERIAL.

The general rule under which the tests are made is that the material shall consist of full-sized pieces used in construction, whether bridge stringers, cross-arms for poles, or wagon spokes. Exceptions are:

(1) That shearing tests are made on small blocks.

(2) That small sticks, about 2 by 2 inches in cross-section and 27 inches long, are cut from the beam so as to be perfectly clear and straight-grained, for the purpose of determining the essential mechanical properties of the particular piece of wood selected. The tests for compression parallel or at right angles to the grain are made on minor-sized pieces.

(3) Other minor tests, for abrasion, impact, etc.

PURCHASE AND STORAGE.

The timber will be purchased or selected under special directions from the Forest Service. Ordinarily the timber may be stored in a shed in such a manner as to prevent rot. In case the timbers are to be tested in a green condition they could be protected from the sun and wind by a cover of some sort. A green state may be defined as a uniform moisture content of over 33 per cent. If the timbers are somewhat dry on the surface, they should be brought to a uniformly

green state by artificial means, either in the soaking tank or by being covered with burlap and sprinkled for a sufficient period of time preceding the test.

HISTORY AND DESCRIPTION.

At the time the timber is selected in the market or at the mill every endeavor should be exerted to obtain the full history of the timber. The foreman of the yard usually has knowledge of the mill and the date of shipment, and of the history of the sticks during the time they have been in his hands. The description of the timber should follow the forms supplied, recording rings per inch, knots, crooked grain, wane, sap, checks, pitch seams, rot, etc. No wood should be tested unless properly identified as to species.

The timber should be dressed on four sides before the test, so that the dimensions may be accurately determined.

PHOTOGRAPHS.

Photographs of both the ends and sides of certain sticks should be taken. When photographs are taken, the surface should be clean and the lighting uniform, without shadows. A contrasting background, either of dark or light cloth, should be provided. Photographs may be made of four sticks at a time. These should be separated by blocks 4 inches apart. The sticks should be photographed from all four sides and both ends. The ends should be planed smooth before photographing. Six plates are thus used for four sticks.

The prints should be of a light tone, in order to show the knots and grain, and should be cut out and rearranged on cards, so that one card will contain the photographs of one stick.

The ends of the sticks should be squared before photographing and the sticks stamped with the proper numbers. The numbering should show the number of the stick, the end with reference to the butt or the top (usually shown by the diameter of the heart or the direction of knots), and the face. (See record in Appendix.) The center of the span under test should be indicated by a line.

After the stick is tested a photograph may be taken of the fractured section.

Where circumstances allow, the most economical method will be to photograph the sticks after the test has been made This will not be advisable, however, in some circumstances, because the period of waiting between the test and the photographing will result in a change of moisture conditions of the beam.

The photographing of sides is for the purpose of obtaining a set of characteristic views of conditions with regard to knots, correctly representing the average and extremes of the series under test. Unusual fractures should be photographed. The use of photographs in publi-

cations should be kept in mind. The photographs of end sections should be to a uniform scale. A convenient scale is such that the end photograph of an 8 by 16 inch stick will measure 4 by 8 inches, and the side photographs will measure 1 inch for every 1 or 2 feet of beam.

PROCEDURE IN TESTING.

The detail of procedure will usually be as follows:

(1) Timber selected, delivered, dressed on four sides and ends squared, described, and given a serial number. If timber is not green, it should be brought to a degree of moisture corresponding to the green state. If it is to be tested in air-dry or kiln-dry state, it should be brought to that condition.

(2) Timber photographed.

(3) Timber measured and weighed. Measurements of cross section to be recorded to 0.01 of an inch.

(4) Timber tested according to instructions.

(5) Fracture described and, if necessary, photographed.

(6) Disks cut from region of rupture and from one of the quarter points for determining moisture and for record of stick.

(7) Pieces cut for minor tests and their location in stick recorded.

(8) These small pieces described, measured, tested, and the moisture determined.

The pieces for minor tests include the following:

One 1-inch disk near the region of rupture; one 1-inch disk near one of the quarter points; a disk 3 inches thick to yield test pieces for shearing test; a piece about four times as long as wide for compression parallel to grain; a piece for compression at right angles to grain; a section of the stick about 30 inches long, from which other pieces for minor tests are to be taken. In some cases a beam of very short span may be taken out with the purpose of determining the load at which such a short beam will rupture under horizontal shear. A disk thick enough to prevent splitting by season checks should be preserved as a record of the timber tested.

PROPERTIES TO BE MEASURED.

Some or all of the following properties will be measured, according to the use of the species:

1. Strength.
2. Stiffness.
3. Resilience.
4. Hardness.
5. Brittleness.
6. Resistance to indentation.
7. Resistance to abrasion.
8. Weight per cubic foot at time of test, and when dry.
9. Shrinkage and swelling.

KINDS OF TESTS.

The kinds of tests to be made in determining these properties will include a part or all of the following:

- Bending, in which will be determined—
  - Fiber stress at elastic limit.
  - Modulus of rupture.
  - Modulus of elasticity.
  - Modulus of elastic resilience.
  - Horizontal shear at rupture.
  - Unit rupture work.[a]
- Compression parallel to grain: Strength and modulus of elasticity.
- Compression at right angles to grain:
  - Elastic limit.
- Shearing: Strength, radial and tangential, parallel to grain.
- Torsion.
- Column.
- Impact: Elastic resilience, rupture-work.
- Spike pulling.
- Hardness.
- Abrasion.
- Shrinkage.
- Tension.

BENDING TEST.

DISCUSSION OF METHODS.

The principal points of controversy in relation to this test are the method of loading, the method of support, the speed of application of load, and the location of elastic limit.

Method of loading.—The measurement for deflections is most simple when the load is applied at the center of the beam. On the other hand, when the load is applied at two points, one-third the length of the span apart, a larger portion of the stick is brought under the maximum stress, and the moment and shear diagrams are nearly those for a uniform loading—the ordinary condition of service. Thus the failure under horizontal shear will be more probable and the failure at knots more certain. Up to September, 1905, the large beams were loaded at the center. From this date they have been loaded at the third points and will continue to be. The measurement of deflection will be at the center, with reference to points over the end supports. (For method of calculation see Appendix IV.) In minor tests center loading will prevail.

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[a] Omitted until further notice.

Method of support.—To prevent local crushing provision should be made for bearing surfaces. The center bearing block should be curved longitudinally to prevent damaging the beam at edge of block. Bearing blocks will be supplied from Washington. In case of large deflection, roller bearings will be needed. Ordinarily, rocking knife edges will suffice.

Measurement of deflection and rate of application of load.—If the testing machine has a rigid head, it is sufficiently accurate to measure deflection on one side of the beam. Loads should be applied continuously at a fixed speed, and the deflections read "on the run." A steel wire is attached to points on the neutral axis directly over the supports and kept taut by a spring. The deflections are read on a scale fixed to the side of the beam at the center back of the wire. A mirror adjoining the scale will increase the accuracy of the readings. A hand glass may be used, and the deflections read to 0.01 inch, which, in view of the large deflection measured and the variability of the product, represents sufficient accuracy. A reading telescope is still better. The telescope of an engineer's transit is serviceable. For minor bending tests a special deflectometer has been designed. (See fig. 2, Appendix V.)

Another method allows the load to be applied some seconds before reading deflections. This involves a variable which may be avoided by the first method. A separate investigation may be made to determine how the results from continuously increasing loads should be modified to apply to fixed loads applied for long intervals of time.

Location of elastic limit.—There is no doubt that there is a point on the load-deformation diagram that indicates an increase in deformation sufficiently marked to be designated the elastic limit. This is the point against which factors of safety should be fixed. In some sticks the location of this point is a matter of judgment.

This exercise of judgment exists in case of tests of steel also, but to a less extent. It was avoided in the former Government timber tests by the location of an arbitrary point called the "apparent elastic limit." This limit was the point of tangency of a line drawn with a slope 50 per cent greater than the slope of the load deflection diagram at the origin.

The elastic limit should be computed from the load deflection curve, and should be the point where the deflection begins to increase faster than the load. (See Appendix III.)

PROCEDURE.

(1) Measure dimensions of beam and weigh: the weight per cubic foot and specific gravity, wet and dry, to be computed from these measurements in conjunction with the moisture determinations. The calculations do not take into account shrinkage. This should form the subject of a special inquiry.

(2) Balance the beam of testing machine at zero while timber rests on the platform. The load, as a rule, should be applied at the center.

(3) The approximate speed of deformation should be 0.0007 of an inch deformation per inch length of outer fiber each minute; the beam to be kept floating beyond the yield point; maximum load to be recorded. Suitable bearing blocks should be used to prevent local crushing of the wood. Loads should be applied continuously, and deflections read by scale and wire on one side of beam. The method of test is shown in figure 1, Appendix V.

(4) Trace cracks and describe nature of rupture.

(5) Mark out and stamp the sticks to be taken from beam for minor tests.

(6) Remove beam from machine and photograph fracture.

(7) Cut disks for moisture, also pieces for minor tests.

DETERMINATION OF MOISTURE.

The moisture content should be determined from a 1-inch disk cut from the region of rupture, and in kiln-dried sticks a supplementary determination should be made on a second disk, taken from the quarter point. In most green and air-dried sticks, the difference in moisture between the center and the quarter point will not be great enough to demand a disk from the latter. The moisture determination should be made on the 1-inch disk by drying it in a drying oven to a constant weight at 100° C.

When a shipment of timber is received for testing, the percentage of moisture in the timber should be determined in advance by examination of disks cut from one representative stick. The disks should be cut from near the ends, at the center, and at the third points between the ends and the center. A disk should be divided into 9 parts by four section lines running between the quarter points on opposite sides. Moisture determinations should then be made on the separate pieces, with a view to determining the distribution of moisture throughout the beam. The necessity of further treatment to reduce the beam to the green state may be judged by the results of this test.

The exact procedure in making moisture determinations is as follows:

(1) Weigh each disk, after loose splinters and rough edges are removed by chisel.

(2) Put the disk in a drying oven at 100° C., and dry until no greater difference of weight than 0.5 per cent of the dry weight remains to be determined. Any resin that runs from the disk should be caught and weighed.

(3) Remove and cool in desiccator.

(4) Weigh.

(5) Determine per cent of moisture with reference to dry weight.

MINOR TESTS.

In order to obtain the mechanical properties due to the different rates of growth of the wood in any large stick, smaller test specimens are cut from large beams. These test pieces should be 2 by 2 inches in cross section with a span of twelve times the height, and should be unaffected by knots or crooked grain. From each stick at least two pieces should be taken, one from the broad-ringed region of the cross section and one from the narrow-ringed region. They should have one side tangential to the annual rings, and should be tested with the annual rings horizontal, and at a speed of deformation of 0.0015 of an inch deformation per inch length of outer fiber each minute. The location in the cross section should be noted in a drawing of the section of the stick. The methods of test are shown in figure 2, Appendix V.

After these small pieces are tested in bending, a portion of the end should be cut off for a compression test parallel to grain. The degree of moisture and volumetric weight of the test pieces should be recorded.

To provide for shrinkage tests, absorption tests, abrasion tests, and impact tests, additional minor test pieces should be taken from the main stick. These pieces should be taken from the clear part of the stick parallel to the grain, and, whenever possible, with two sides tangential to the annual rings. The sizes are as follows: Shrinkage test, 3 by 3 by 12 inches; abrasion test, 4 by 6 by 6 inches; impact test, 2 by 2 by 30 inches. The location of these test pieces should be recorded by a drawing.

COMPRESSION TEST.

PARALLEL TO GRAIN.

The directions will apply to minor tests.

(1) Cut full-sized test pieces from uninjured ends of beams; length should be 4 times the width.

(2) Square ends with saw, measure dimensions, locate knots and defects, and ascertain rings per inch.

(3) Weigh.

(4) Apply load continuously at rate of 0.003 of an inch deformation per inch length of specimen each minute. Use spherical bearing, and read amount of deflection corresponding to loads on two deflectometers placed on two opposite sides of test piece until failure occurs. In certain cases when the exact deformations of the test pieces are to be determined apart from the local compression at the heads of testing machine for computation of the modulus of elasticity, the Olsen compressometer reading to 0.0001 of an inch should be used to measure the deformation between steel yokes. The method of measurement is shown in figure 3, Appendix V.

(5) Describe character of failure.

(6) Determine moisture in test pieces, when necessary, by disk method.

(7) Compute elastic limit and crushing strength parallel to grain.

AT RIGHT ANGLES TO GRAIN.

The former Government tests were made on sticks of definite section, and the results gave the load which caused a compression of 3 and 15 per cent respectively. These results have little significance for other sizes of timber. The method planned is to apply loads in increments across the stick and measure the accompanying deformations of the test piece in order to determine the load at the yield point of the timber. The method of test is shown in figure 4, Appendix V. The tests will be supplemented by what may be termed indentation tests, in which the load required to bring about the penetration of a punch of given area to a given depth will be determined.

(1) Use full-sized minor pieces from uninjured portion of beam, length to be sufficient to prevent failure by shear along grain. Pieces to be cut whenever possible so as to distinguish strength tangential and radial to annual rings.

(2) Measure dimensions, locate knots and defects, and ascertain the rings per inch.

(3) Weigh.

(4) Apply load at rate of 0.015 of an inch of deformation per inch of height per minute to full width of block and along 4 inches of length. Read loads and deformations with reference to base of stick until failure occurs.

(5) Describe character of failure.

(6) Determine moisture by disk method.

(7) Compute stress per square inch of surface at elastic limit.

SHEARING TEST PARALLEL TO GRAIN.

Various methods of determining the shearing strength have been used. The difficulty is to obtain a pure shear unaccompanied by splitting of the test piece due to bending. This difficulty is often met in case of double shear under tension test. The test piece and method of test are more simple in compression than in tension. Compression tests can be applied properly only for the determination of single shear. The latter is more satisfactory in that the failure occurs on only one surface, and the exact stress may be determined. The shearing tests are being made in compression in single shear, by a tool designed for that purpose. The values obtained by shearing tests on small pieces should be modified by the results of the tests on large beams, for which the shearing stress at the neutral axis should be calculated.

(1) Select four test pieces from the cross section of stick to yield the radial and tangential shearing strength for close-ringed and wide-ringed timber. These test pieces should consist of blocks 3 by $3\frac{1}{2}$ by $1\frac{1}{2}$ inches, with a projecting bead 2 by $3\frac{1}{2}$ by $\frac{5}{8}$ inches, which is to be sheared off. The grain of the wood must be parallel to the direction of the projecting bead, which may be slightly undercut. (2) Apply load continuously at speed of 0.015 of an inch per minute. (3) Note maximum load and manner of failure of test piece.

Tool for use in shearing is shown in figure 5, Appendix V.

TORSION TEST.

The torsion test is a special test, and will be made on but few sticks. It exhibits well the length of fiber and toughness of the wood. Special instructions will be issued in connection with this test to the engineer at whose laboratory the work is being carried on. The test pieces should be cylindrical, 2 inches in diameter and 2 feet gage length, with square ends. The load should be applied continuously and the angle of torsion measured to correspond with the various increments of load.

COLUMN TEST.

As in bending test. Instructions not yet determined.

IMPACT TEST.

METHODS.

In determining the relative brittleness of different timbers, tests in compression and bending will be made. In case of compression tests and bending tests the test pieces should be 2 by 2 by 4 inches, and 2 by 2 by 30 inches, respectively. The material to be tested should be described as directed in the case of static tests.

Three kinds of tests are distinguished with respect to the time of application:

(*a*) When a constant load is applied to a test piece and allowed to remain for a long period of time; (*b*) when increasing loads are applied continuously throughout a period of from ten to twenty minutes until the piece fails; (*c*) when the load is applied through the medium of a blow under which the test piece fails in a small fraction of a second. Under *a* we have the case of a load such as is produced by books on a library shelf; under *b* we have the ordinary testing process from which the strength of materials to carry static loads is almost universally determined, and the test referred to as "static test;" and under *c* we have the case of a shock or impact such as occurs in parts of implements or vehicles.

The present state of our knowledge is that under *a* the elastic limit and ultimate strength of wood are probably one-quarter less than under

b; under *c* the elastic limit is twice that under *b*—that is to say, the rate of deformation has an important effect on the elastic strength of wood.

THE IMPACT MACHINE.

A machine has been devised by the author for making impact tests for the Forest Service, the mechanical details of which were worked out and the construction supervised by Prof. W. P. Turner, of Purdue University. Its essential parts are: (*a*) A base or anvil weighing 3,500 pounds, allowing a specimen 5 feet long to be tested in flexure; (*b*) a set of hammers of 250, 100, and 50 pounds weight, respectively, lifted by an electro-magnet and automatically released at a predetermined height by a catch which trips a trigger and breaks the electric circuit; (*c*) guides for these hammers, 7½ feet in length, surmounted by an electric motor that lifts or lowers the hammer; (*d*) a rotating drum on which a pencil attached to the hammer records a curve during the descent of the latter; (*e*) a tuning fork which enables the speed of the drum to be computed. This machine is shown in its essential parts in figure 6, Appendix V.

IMPACT TESTS UNDER A NUMBER OF BLOWS.

The resistance of a specimen of wood under impact is usually determined by dropping a given weight from successively increasing heights. The successive amounts of deformation and set of the specimen and rebound of the hammer are recorded on the drum. The elastic strength of the specimen is fixed at that limit at which the deflection suddenly increases. At this limit a sudden increase in the set of the specimen, as well as a maximum amount of rebound of the hammer, usually occurs.

In making the test the hammer is allowed barely to touch the upper surface of the specimen, and a light line is then drawn on the drum. The weight of the hammer is then allowed to rest upon the specimen, a zero or datum line is drawn, and the deflection under the dead weight of the hammer is noted. Then blows of a weight dropped from increasing heights are delivered to the specimen, and records taken on the drum. A sample record is seen in figure 6*a*, Appendix V.

The height of the drop at which any rupture of the specimen occurs is noted, together with other phenomena of test. Sample log sheets and calculations will be found in the Appendix.

The machine is calibrated in advance to determine the proportion of the height of fall which is not effective because of friction and lag of magnet.

IMPACT TEST UNDER A SINGLE BLOW.

Occasionally the beam is ruptured under a single blow of the hammer falling from a height greater than that necessary to rupture the specimen. In this case the residual energy resident in the hammer, after rupture of the specimen, must be determined in order that the amount of energy used up in rupturing the specimen may be known.

The zero or datum line is determined as before, the hammer is released from a height greater than that necessary to rupture the specimen, and a record is taken of the circumstances of the impact. The tuning fork must be held on the drum during impact. A sample record is shown in figure 6*b*, Appendix V.

The theory of calculation of the test under a single blow is developed as follows:

Before contact of the hammer with the specimen, AB (see fig. 6*b*), the curve recorded on the drum, is a parabola of free fall. The hammer is then retarded by the resistance of the beam, as shown by the curve BC. At C complete failure occurs, and the record is again a parabola of free fall.

The use of this drum record in computing the desired quantities depends upon the following considerations: Neglecting, for the present, losses of energy due to friction and yielding of the parts of the apparatus, let us suppose that the hammer falls from the point of release, a height $h + h'$, to some point D taken on the parabola of free fall subsequent to rupture. (The point C might have been selected, but the selection of the point D offers more favorable conditions for graphical work.) The entire quantity of work represented by the product of the weight of the hammer G by the distance $h + h'$ is accounted for:

(1) By the work expended upon the resistance of the test specimen during deflection.

(2) By the energy remaining in the hammer at D.

In the form of an equation.

$$G\,(h + h') = \text{work on test specimen} + \tfrac{1}{2}\,M\,V_d^2$$
$$M = \text{mass of } G$$
$$V_d = \text{velocity at } D$$

The quantity $\frac{1}{2}\,M\,V_d^2$ may be considered as replaced by the quantity Gh_d where h_d = the velocity head at D.

$$G\,(h + h') = \text{work on test specimen} + Gh_d$$

Or,

$$\text{Work on test specimen} = G\,(h + h' - h_d)$$

h and h' are directly measured, while h_d is determined from the computed velocity v_d. This latter quantity is determined by the relation of measured distances l' and l'' in conjunction with the tuning fork record. Thus, comparing l'' with the tuning fork record, the time

represented by l'' and therefore by l' is known. The velocity at D, V_d, is the distance l' divided by the time.

The rupture work per cubic unit of the beam is obtained by dividing the work $G\ (h + h' - h_d)$ by the volume of the beam between supports.

SPIKE-PULLING TEST.

In determining the spike-holding properties of various woods, common and screw-spikes are pulled from full-sized ties. The number of pounds directed along the length of the spike required to pull it is determined. The method of test and size of spike to be used are shown in figure 7, Appendix V.

HARDNESS TEST.

An investigation will be made to determine appropriate methods of test. The method contemplated involves a measurement of the width of scratch made by a prescribed tool under a prescribed pressure. No instructions have as yet been prepared.

ABRASION TEST.

The machine for making this test is a modified form of the Dorry abrasion machine, shown in figure 8, Appendix V. Small blocks of wood are fixed in the clamps and held against a revolving horizontal disk upon which is glued a commercial sandpaper, known as garnet paper, which is generally used in factories for finishing wooden products. The garnet paper wears down the specimen and the depth of wear under a prescribed number of revolutions (1,000) at a rate of 68 per minute is a measure of the resistance of the specimen to abrasion. In making the test a standard species of wood is held in one clamp and the sample to be tested in the opposite clamp, so that a comparison of the two will not be affected by any change in the conditions of the surface of the garnet paper which is changed after the surface becomes worn to a noticeable degree. The speed of rotation, pressure on specimen, and number of revolutions have been fixed after considerable preliminary experimentation.

SHRINKAGE TEST.

The specimen selected is 3 by 3 by 12 inches, with sides parallel to radial and transverse direction of trunk, and length parallel to grain. The deformation should be measured during the change from the green to the dry state by the change of position of reference marks on brass nails driven into the wood.

TENSION TEST.

On account of the difficulty of making the tension test along the grain and the minor importance of the results, this test will, in general, be omitted. The tensional strength in the direction perpendicular to grain is, however, of more importance. It is recommended that, for the present, engineers of tests study the problem of determining the values representing this latter strength in case of specimens from a few of the beams under test.

An apparently suitable method for tension tests of wood in any direction has been designed by Mr. L. E. Hunt, of the Forest Service. A rod of wood about 1 inch in diameter is bored by a hollow drill from the stick to be tested. The ends of this rod are inserted and glued in corresponding holes in permanent hardwood wedges. The specimen is then submitted to the ordinary tension test. The broken ends are punched from the wedges. The arrangement is shown in figure 9, Appendix V.

RECORD AND CALCULATION OF RESULTS.

The results desired are best shown in the form of sample reports, which are here attached in Appendixes I to IV.

Explanatory Note.

On account of inquiries regarding the significance of the various functions, such as the elastic limit, modulus of rupture, modulus of elasticity, etc., quoted in the publications of the Forest Service, the following explanation is given:

The elastic limit is a measure of the elastic strength of wood, whether in compression (as a post) or in bending (as a beam). Below this limit of stress the material suffers no permanent deformation under a test load, but comes back to its original form when the load is removed.

The modulus of rupture is a measure of the breaking strength of a beam. The crushing strength is a measure of the breaking strength of a post.

The modulus of elasticity is a measure of the stiffness of wood. A large modulus indicates a stiff material, one that deforms but little under the action of a load.

The modulus of resilience is a measure of the "springiness" of the material. For instance, hickory has a large modulus of resilience.

APPENDIX I.

SAMPLE DESCRIPTION OF MATERIAL AND LOG SHEETS OF MECHANICAL TESTS.

UNITED STATES DEPARTMENT OF AGRICULTURE—FOREST SERVICE.

TIMBER TESTS.

SERIES I.—TIMBER FROM THE MARKET.

Testing station *University of California*

Stick number *67* Shipment number *88*

Market name *Western hemlock*

Species *Tsuga heterophylla*

Dimensions *7.55″×15.50″×17.19 ft.*

Obtained from *Booth, Kelley Lumber Co., Saginaw, Ore.*

History *Material cut in T. 20 E., R. 1 E., Willamette meridian, W. slope of Cascade Mts., Lane Co., Oreg. Shipped from Saginaw, May 12. Rec'd at Berkeley, May 25, '03*

Air or kiln dried *Green timber*

Market grading and standard used *No. 2 Pacific Coast Standard 1900*

Imperfections *Side a 15 knots, weather checked*

" b 6 " " "

" c 15 " " "

" d 5 " " "

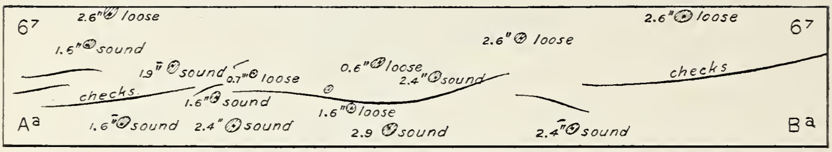
Per cent sap *None*

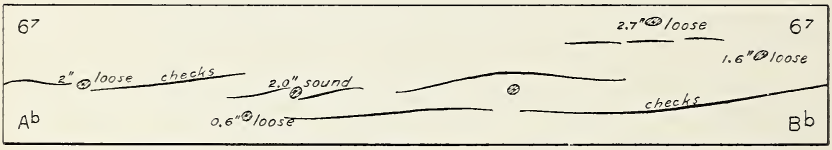
Rate of growth *7 rings per inch*

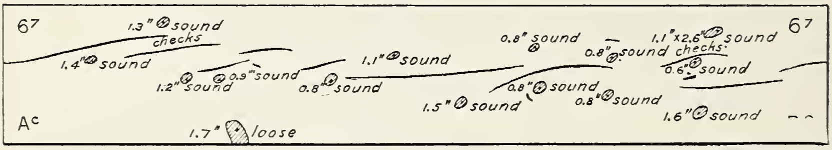
Photographs *4 sides and 2 ends*

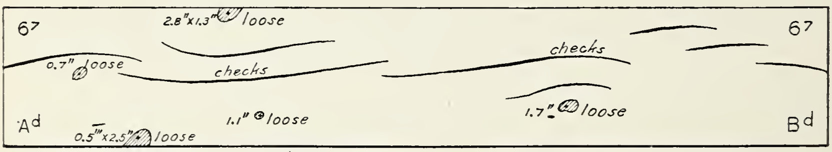
Date *September 5, 1903*

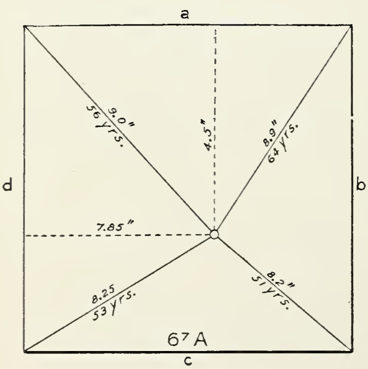
Remarks

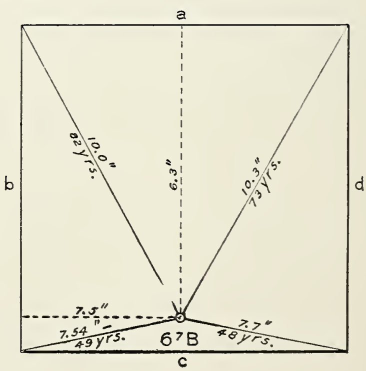

6⁷
2.6" loose
1.5" sound
1.9" sound
0.7" loose
0.6" loose
2.4" sound
2.6" loose
2.6" loose
6⁷
checks
checks
1.6" sound
1.6" loose
Aa
1.6" sound
2.4" sound
2.9 sound
2.4" sound
Ba


6⁷
2.7" loose
6⁷
1.6" loose
2" loose
checks
2.0" sound
checks
Ab
0.6" loose
Bb


6⁷
1.3" sound
checks
0.8" sound
1.1"x2.6" sound
6⁷
1.4" sound
1.1" sound
0.8" sound
checks
0.6" sound
1.2" sound
0.9" sound
0.8" sound
0.8" sound
1.5" sound
0.8" sound
1.6" sound
Ac
1.7" loose


6⁷
2.8"x1.3" loose
6⁷
checks
0.7" loose
checks
Ad
1.1" loose
1.7" loose
0.5"x2.5" loose
Bd


a
d
b
c
9.0"
56 yrs.
4.5"
8.9"
64 yrs.
7.85"
8.25
53 yrs.
8.2"
51 yrs.
6⁷ A


a
b
d
c
10.0"
82 yrs.
6.3"
10.3"
73 yrs.
7.5"
7.54"
49 yrs.
7.7"
48 yrs.
6⁷ B

UNITED STATES DEPARTMENT OF AGRICULTURE—FOREST SERVICE.

TIMBER TESTS.

STATIC TEST—BENDING—CENTER LOADING.

Lab. No. *2361* Series No. *1* Laboratory *University of California*

Species *Tsuga heterophylla* Date of test *11-5-04*

Stick No. *218* Mark

Width *7.68* in. Height *15.52* in. Length *17.32 ft*

Weight *402.5 lbs.* Rings per in *14.5*

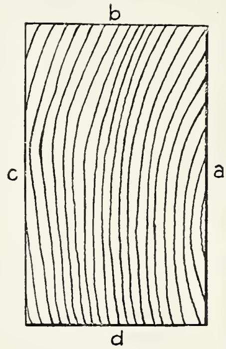
Grain *See sketch* Per cent of sap *None*

Grade *Merchantable* Span *16 ft*

Machine *200,000# Olsen* Speed *0.250 in per min*

Photographs

Defects *See description*



Sketch.

Per cent of moisture *24.3* Specific gravity (dry) *0.360*

Fiber stress at elastic limit *3,260* lbs. per sq. in.

Modulus of rupture *5,560* lbs. per sq. in.

Modulus of elasticity *1,240* 1,000 lbs. per sq. in.

Calculated greatest shearing stress *225* lbs. per sq. in.

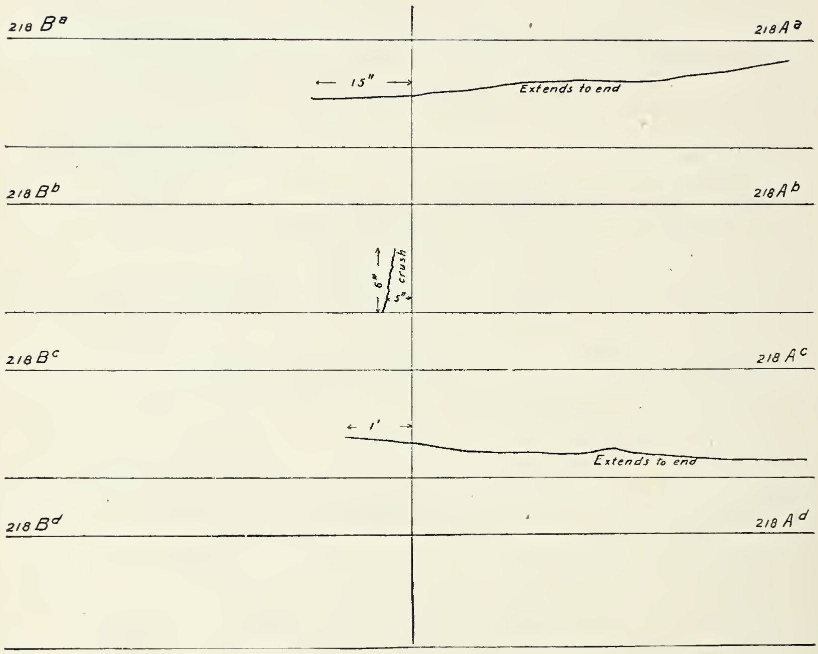
Modulus of resilience *0.48* in.-lbs. per cu. in.

Rupture work in.-lbs. per cu. in.

Manner of failure *Crushing followed by longitudinal shear*

Time.			Load.	Deflection reading.	Reading.	Reading.	Deflection.	Remarks.
Hr.	Min.	Sec.	Lbs.	Inches.	S.		In.	
0	0	0	000	3.57			0.00	Supported at center 3.52
			2,000	3.67			0.12	
			4,000	3.77			0.22	
			6,000	3.87			0.32	
			8,000	3.97			0.42	
			10,000	4.07	1,553		0.52	
			12,000	4.16			0.61	
			14,000	4.25			0.70	
			16,000	4.36			0.81	
			18,000	4.46			0.91	
			20,000	4.57			1.02	
			22,000	4.67			1.12	
			24,000	4.78			1.23	
			26,000	4.91			1.36	
			28,000	5.05			1.50	
			30,000	5.20			1.65	Begins to crush.
0	7	20	32,000	5.41			1.86	
			34,000	5.67			2.12	
			[a] 35,810	6.17			2.62	Failed by longitudinal shear.

[a] Maximum load.


218 B^a
218 A^a
← 15″ →
Extends to end
218 B^b
218 A^b
6″
crush
5″
218 B^c
218 A^c
← 1′ →
Extends to end
218 B^d
218 A^d

United States Department of Agriculture—Forest Service.

TIMBER TESTS.

STATIC TEST—BENDING—THIRD POINT LOADING.

Lab. No. *5431* Series No. *161* Laboratory *Purdue University*

Species *Pinus ponderosa* Date of test *6-23-05*

Stick No. *105-1092* Mark

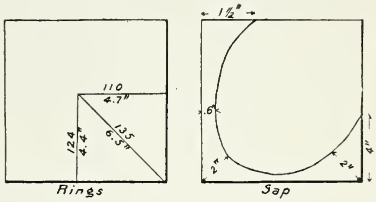
Width *8.11* in. Height *8.26* in.

Length *132* in.

Weight *141.5 #* Rings per in. *23.5*

Grain *See sketch*

Per cent of sap *20*



Sketch.

Grade *Bridge tie* Span *80* in.

Machine *300,000 # Riehle* Speed *.13* in. per min.

Photographs

Defects *See sketch*

Per cent of moisture *17.1* Specific gravity (dry) *.378*

Fiber stress at elastic limit *2310* lbs. per sq. in.

Modulus of rupture *4320* lbs. per sq. in.

Modulus of elasticity *866* 1,000 lbs. per sq. in.

Calculated greatest shearing stress *335* lbs. per sq. in.

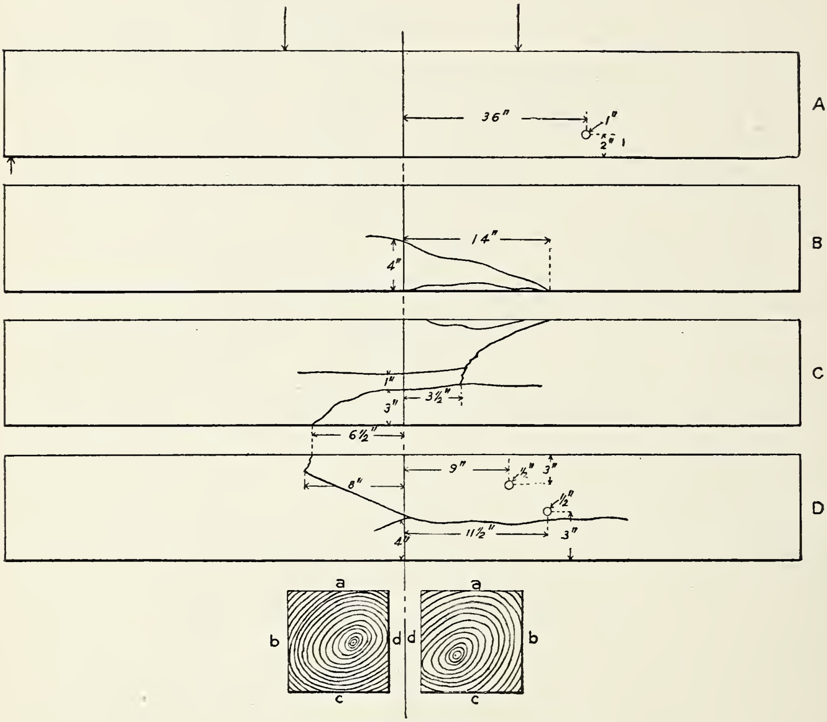
Modulus of resilience *0.57* in.-lbs. per cu. in.

Rupture work in.-lbs. per cu. in.

Manner of failure *Tension.*

Time.			Load.	Deflection reading.	Reading.				Deflection.	Remarks.		
Hr.	Min.	Sec.	Lbs.	Inches.	*Left ⅓ pt.*	*Center.*	*Right ⅓ pt.*		Inches.	*Deflection in inches.*		
10	*36*	*30*	*500*		*2.88*	*3.34*	*3.12*			*0.00*	*0.00*	*0.00*
			2,000		*2.91*	*3.38*	*3.15*			*.03*	*.04*	*.03*
			4,000		*2.96*	*3.44*	*3.20*			*.08*	*.10*	*.08*
			6,000		*3.01*	*3.50*	*3.24*			*.13*	*.16*	*.12*
			8,000		*3.05*	*3.55*	*3.28*			*.17*	*.21*	*.16*
			10,000		*3.10*	*3.60*	*3.34*			*.22*	*.16*	*.22*
			12,000		*3.14*	*3.66*	*3.38*			*.26*	*.32*	*.26*
			14,000		*3.19*	*3.71*	*3.43*			*.31*	*.37*	*.31*
			16,000		*3.24*	*3.76*	*3.48*			*.36*	*.42*	*.36*
			18,000		*3.28*	*3.82*	*3.52*			*.40*	*.48*	*.40*
			20,000		*3.34*	*3.89*	*3.58*			*.46*	*.55*	*.46*
			22,000		*3.39*	*3.95*	*3.63*			*.51*	*.61*	*.51*
			24,000		*3.46*	*4.01*	*3.70*			*.58*	*.67*	*.58*
			26,000		*3.52*	*4.10*	*3.77*			*.64*	*.76*	*.65*
			28,000		*3.58*	*4.16*	*3.84*			*.70*	*.82*	*.72*
10	*45*	*20*	*29,900*		*Maximum Load.*							

Sudden brash tension failure.



Sketch 161-105-1092.

UNITED STATES DEPARTMENT OF AGRICULTURE—FOREST SERVICE.

TIMBER TESTS.

STATIC TEST—BENDING.

Lab. No. *3470* Series No. *109* Laboratory *Purdue University*

Species *Pinus tæda* Date of test *March 22-05*

Stick No. *102-1043* Mark *D-4*

Width *2.04* in. Height *2.02* in.

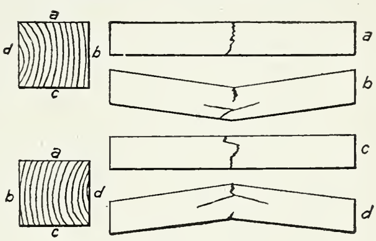
Length *36.22* in.

Weight *1,546.3 g.* Rings per in. *8*

Grain *Straight* Per cent of sap *100*

Grade *Clear* Span *34* in

Machine *Falkenau* Speed. *.27* in. per min.



Sketch of failure.

Photographs

Defects *None*

Per cent of moisture *28.2* Specific gravity (dry) *0.492*

Fiber stress at elastic limit *5,200* lbs. per sq. in.

Modulus of rupture *10,400* lbs. per sq. in.

Modulus of elasticity *1,940* 1,000 lbs. per sq. in.

Calculated greatest shearing stress *309* lbs. per. sq. in.

Modulus of resilience *.77* in.-lbs per cu. in.

Rupture work in.-lbs. per cu. in.

Manner of failure *Compression*

Time.			Load.	Deflection reading.	Reading.	Load.	Deflection.	Remarks.
Hr.	Min.	Sec.	Lbs.	In.		Lbs.	In.	
1	*30*	*40*						
			50	*0.000*		*1,590*		*Compression*
			100	*.020*		*1,700*		*Max. load Sudden failure*
				.038				
			200	*.050*				
				.063				
			300	*.078*				
				.091				
			400	*.105*				
				.118				
			500	*.132*				
				.147				
			600	*.163*				
				.178				
			700	*.193*				
				.210				
			800	*.225*				
1	*37*	*46*		*.240*				

NOTE: This test is special with respect to length and span and disposition of rings.

UNITED STATES DEPARTMENT OF AGRICULTURE—FOREST SERVICE.

TIMBER TESTS.

STATIC TEST—COMPRESSION.

Lab. No. *3028* Series No. *105* Laboratory *Purdue University*

Species *Pinus tæda* Date of test *Feb. 15–05*

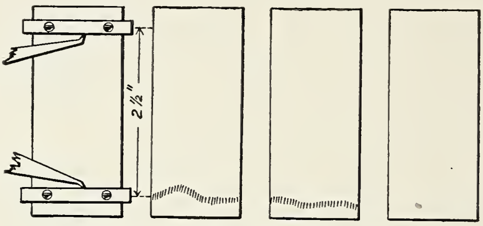
Stick No. *96–974*

Mark *B-4*

Length *4.04* in. Cross sec. *2.02* in. X *2.00* in. Weight *201 gms.*

Rings per in. *5*

Grade *Clear*



Per cent of sap *100*

Sketch showing position in machine and failure.

Machine *30,000 Olsen* Speed *0.012* in. per min.

Photograph *None* Defects *None*

Per cent of moisture *67.4* Specific gravity (dry) *0.448*

Compressive strength at elastic limit *2,730* lbs. per sq. in.

Crushing strength *3,460* lbs. per sq. in.

Modulus of elasticity *1,450* 1,000 lbs. per sq. in.

Time.			Load.	Reading.	Compression.	Load in.	Compression.	Remarks.
Hr.	Min.	Sec.	Lbs.	In.	In.	Lbs. per sq. in.	In. per in.	
			500	*0.0000*				
			1,000	*.0002*				
			2,000	*.0006*				
			3,000	*.0010*				
			4,000	*.0015*				
			5,000	*.0020*				
			6,000	*.0024*				
			7,000	*.0028*				
			8,000	*.0032*				
			9,000	*.0036*				
			10,000	*.0040*				
			11,000	*.0044*				
			12,000	*.0050*				
			13,000	*.0057*				
			13,950					*Max. load.*

UNITED STATES DEPARTMENT OF AGRICULTURE—FOREST SERVICE.

TIMBER TESTS.

STATIC TEST—COMPRESSION.

Lab. No. *2373* Series No. *1* Laboratory *University of California*

Species *Tsuga heterophylla* Date of test *11–14–04*

Stick No. *218 A* Mark *218 A*

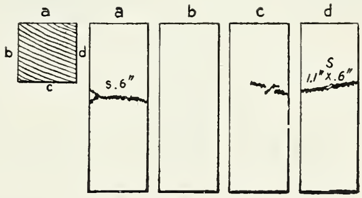
Height *30.00* in.

Cross sec. *5.96* in.

X *5.96* in.

Weight *7.9 kg*

Rings per in. *12.4*



Sketch showing position in machine and failure.

Grade

Per cent of sap *None*

Machine *200,000# Olsen*

Speed *.10* in. per min.

Photograph

Defects *See sketch*

Per cent of moisture *23.9*

Specific gravity (dry) *.364*

Compressive strength at elastic limit *2,325* lbs. per sq. in.

Crushing strength at maximum load *3,135* lbs. per sq. in.

Modulus of elasticity ____ 1,000 lbs. per sq. in.

Time.			Load.	Reading.	Compression.	Load in.	Compression.	Remarks.
Hr.	Min.	Sec.	Lbs.		In.	Lbs. per sq. in.	In. per in	
0	*0*	*0*	*5,000*	*0.000*				
			10,000	*0.009*				
			20,000	*0.021*				
			30,000	*0.035*				
			40,000	*0.046*				
			50,000	*0.058*				
			60,000	*0.070*				
			70,000	*0.082*				
			80,000	*0.095*				
			90,000	*0.108*				
			100,000	*0.125*		*2,815*		
0	*1*	*31*	*110,000*	*0.151*				
			112,360	*0.180*		*3,135*		*Maximum load.*

UNITED STATES DEPARTMENT OF AGRICULTURE—FOREST SERVICE.

TIMBER TESTS.

STATIC TEST—COMPRESSION.

Lab. No. *2390* Series No. *1* Laboratory *University of California*

Species *Tsuga heterophylla* Date of test *11-18-04*

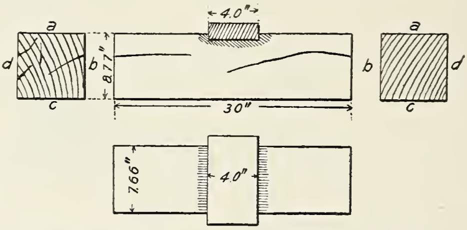
Stick No. *218* Mark *218A*

Length *30.00* in.

Cross sec. W. *7.66* in. X H *8.77* in.

Weight *15Kg*

Rings per in. *11.9*



Sketch showing position in machine and failure.

Grade ______ Per cent of sap *None*

Machine *200,000 # Olsen* Speed *.113* in. per min.

Photograph ______ Defects *None*

Per cent of moisture *24.7* Specific gravity (dry) *.367*

Crushing strength at elastic limit *deformation=1.02%* *395* lbs. per sq. in.

Crushing strength *" =3.00%* *583* lbs. per sq. in.

Modulus of elasticity ______ 1,000 lbs. per sq. in.

Time			Load	Reading	Compression	Load in	Compression	Remarks
Hr.	Min.	Sec.	Lbs.		In.	Lbs. per sq. in.	In. per in.	
	0	0	500	0.000				
			2,000	0.035				
			4,000	0.055				
			6,000	0.068				
			8,000	0.080				
			10,000	0.095		329		
			12,000	0.112				
			14,000	0.151				
			16,000	0.215				
			18,000	0.302				
	3'	30	20,000	0.395				Speed changed
			22,000	0.480				
			24,000	0.600				
			26,000	0.708				
			28,000	0.815				
	6	20	30,000	1.060		987		

United States Department of Agriculture—Forest Service.

TIMBER TESTS.

STATIC TEST—COMPRESSION.

Lab. No. *3557* Series No. *109* Laboratory *Purdue University*

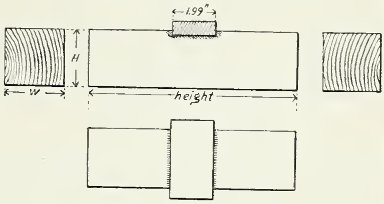
Species *Pinus tæda* Date of test *March 27, 05*

Stick No. *102-1043* Mark *D-4*

Length *5.99* in. Cross sec. W *2.02* in. X H *2.01* in.

Weight *251.0 gr.* Rings per in. *8*

Grade *Clear* Per cent of sap *100*



Sketch showing disposition in machine.

Machine *30,000# Olsen* Speed *.03* in. per min.

Photograph *No. 38* Defects *None*

Per cent of moisture *26.2* Specific gravity (dry) *.498*

Crushing strength at elastic limit *597* lbs. per sq. in.

Crushing strength at maximum load ______ lbs. per sq. in.

Modulus of elasticity ______ 1,000 lbs. per sq. in.

Time			Load	Reading	Compression	Load in	Compression	Remarks
Hr.	Min.	Sec.	Lbs.		In.	Lbs. per sq. in.	In. per in.	
			100	0.100				
			200	.103				
			400	.106				
			600	.108				
			800	.110				
			1,000	.111				
			1,200	.113				
			1,400	.114				
			1,600	.116				
			1,800	.118				
			2,000	.120				
			2,200	.122				
			2,400	.124				
			2,600	.129				
			2,800	.134				
			3,000	.141				
			3,200	.150				

United States Department of Agriculture—Forest Service.

TIMBER TESTS.

SHEARING TEST.

Lab. No. *2422* *2423* Series No. *1* Laboratory *University of California*

Species *Tsuga heterophylla* Date of test *11-17-04*

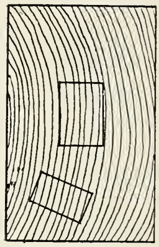
Stick No. *218* Mark *218 B*

Cross sec. in shear. *1.45* in. X *3.30* in.

Per cent of sap *None* Rings per in. *2422-12.0* *2423-11.5*

Machine *30,000# Olsen* Speed *.01* in. per min.

Photograph



Sketch.

Defects *None.*

Weights *2422-108 0 gr.* *2423-109.4 gr.*

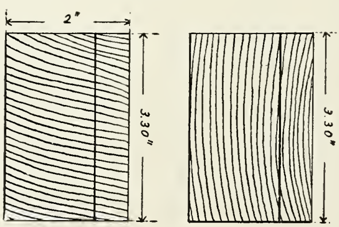
Per cent of moisture *2422-21.5* *2423-21.6* Specific gravity (dry) *2422-.358* *2423-.363*

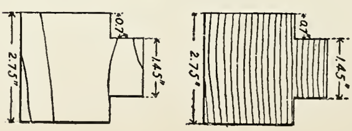
Radial shear (single) *496* lbs. per sq. in.

Tangential shear (single) *671* lbs. per sq. in.

Load at failure lbs. Remarks

Lab. No.	Time.	Load at failure.
2422	*2m 48s*	*3215#*
2423	*2m 30s*	*2375#*





UNITED STATES DEPARTMENT OF AGRICULTURE—FOREST SERVICE.

TIMBER TESTS.

IMPACT TEST—COMPRESSION.

Lab. No. *2613* Series No. *103* Laboratory *St. Louis*

Species *Pinus tæda* Date of test *January 21–05*

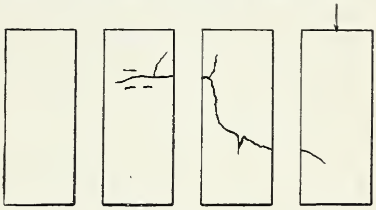
Stick No. *72–737* Mark *D–6*

Height *3.99* in. Cross sec *1.99* in.

X *2.00* in.

Weight *280.2g.* Rings per in. *5 1-2*

Grade *Clear* Per cent of sap *100*



Sketch showing disposition in machine and failure.

Machine *U. S. Impact* Photograph

Defects *None*

Per cent of moisture *30.0* Specific gravity (dry) *0.496*

Crushing strength at elastic limit *47.7 inch* -lbs. per *cu in.*

Crushing strength at maximum drop *95.1* " -lbs. per "

Modulus of elasticity

Manner of failure *Shearing*

No. of blow.	Height of drop in inches.	Deflection in inches.	Rebound in inches.	Set in inches.	Difference of head inches.	Total energy absorbed in. -lbs.	Remarks. Weight of hammer 50 lbs.
1	3.08	.03	1.25				
2	6.10	.04	2.78				
3	9.10	.04	4.01				
4	12.10	.05	4.81				
5	15.10	.06	5.79	0.01			
6	18.10	.06	5.95	.01			
7	21.10	.07	5.94	.01			*Slight shear at middle*
8	24.10	.07	6.64	.01			
9	27.10	.08	6.19	.01			
10	30.10	.10	5.40	.02			*Complete failure by shear*

UNITED STATES DEPARTMENT OF AGRICULTURE—FOREST SERVICE.

TIMBER TESTS.

IMPACT TEST—BENDING.

Lab. No. *3487* Series No. *109* Laboratory *Purdue University*

Date of test *March 23, 1905* Species *Pinus tæda*

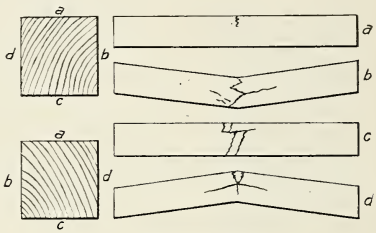
Stick No. *102–1043* Mark *D–1*

Width *2.05* in. Height *2.04* in.

Length *36.02* in. Weight *1,568 gr.*

Rings per in. *7* Grain *Straight*

Per cent of sap *100*



Sketch of failure.

Grade *Clear*

Machine *U. S. Impact* Span *34* in.

Photographs

Defects *None*

Per cent of moisture *28.9* Specific gravity (dry) *.492*

Fiber stress at maximum drop ________ lbs. per sq. in.

Fiber stress at elastic limit *8,540* lbs. per sq. in.

Modulus of elasticity *1,300* 1,000 lbs. per sq. in.

Modulus of resilience *3,112* in.-lbs. per cu. in.

Manner of failure *Sudden tension failure*

No. of blow.	Height of drop in inches. s	Deflection in inches. d	Rebound in inches.	Set in inches.	Difference of head inches. H	$(d+d')^2$	Remarks. Weight of hammer *50* lbs. $d'=.02''$
1	2.26	.30	1.73	.00	2.56	.102	
2	4.26	.41	3.12	.01	4.67	.185	
3	6.26	.52	4.32	.02	6.78	.292	
4	8.26	.60	5.27	.03	8.86	.384	
5	10.26	.70	6.53	.04	10.96	.518	
6	12.26	.78	7.28	.05	13.04	.640	
7	14.26	.86	8.06	.06	15.12	.774	
8	16.26	.95	8.70	.08	17.21	.941	
9	18.26	1.05	9.26	.10	19.31	1.145	*Complete failure by tension at center.*
10	20.26						

APPENDIX II.

COMPUTATION OF VARIOUS FUNCTIONS OF STRENGTH AND SPECIFIC GRAVITY ENTERED ON PRECEDING LOG SHEETS.

(Computation sheet when filed should be attached with clip to log sheet.)

(See page 45.)

IMPACT BENDING.

109–102–1043 D–1.

E. L. $=\frac{3\times 50\times 8.86\times 34}{.62\times 2.05\times 2.04\times 2.04}=85.50.$

E. $=\frac{\text{E. L.}\times 192.7}{2.04\times 0.62}=1,300,000.$

M. Ri. $=\frac{50\times 8.86}{34\times 2.05\times 2.04}=3.11.$

Sp. gr. $=\frac{1,568}{1.289\times 2.05\times 2.04\times 36.02\times 16.4}=0.492.$

STATIC BENDING.

109–102–1043 D–4.

J. $=\frac{0.75\times 1,700}{2.04\times 2.02}=309.$

M. R. $=\frac{\text{J}\times 68}{2.02}=10,400.$

E. L. $=\frac{\text{M. R.}\times 850}{1,700}=5,200.$

E. $=\frac{\text{E. L.}\times 192.7}{2.02\times 0.255}=1,940,000.$

Sp. gr. $=\frac{1,546.3}{1.282\times 36.22\times 2.04\times 2.02\times 16.4}=0.492.$

M. Ri. $=\frac{850\times .255}{34\times 2.04\times 2.02\times 2}=0.77.$

STATIC COMPRESSION PARALLEL TO GRAIN.

105–96–974 B–4.

C. S. $=\frac{13,950}{2.00\times 2.02}=3,460.$

E. L. $=\frac{11,000}{2.00\times 2.02}=2,730.$

E. $= \frac{\text{E. L.} \times 2.50}{.0047} = 1{,}450{,}000.$

Sp. gr. $= \frac{201 \times 0.061}{1.674 \times 2.00 \times 2.02 \times 4.04} = 0.448.$

STATIC BENDING.

Santa Fe Bridge Tie.

161–105–1092.

J. $= \frac{0.75 \times 29{,}900}{8.11 \times 8.26} = 335.$

M. R. $= \frac{4 \times \text{J} \times 80}{3 \times 8.26} = 4{,}320.$

E. L. $= \frac{\text{M. R.} \times 16{,}000}{29{,}900} = 2{,}310.$

E. $= \frac{\text{E. L.} \times 80 \times 80}{4.7 \times 0.44 \times 8.26} = 866{,}000.$

Sp. gr. $= \frac{141.5 \times 1{,}728}{132 \times 8.11 \times 8.26 \times 1.171 \times 62.5} = 0.378.$

M. Ri. $= \frac{16{,}000 \times 0.44 \times 0.435}{80 \times 8.11 \times 8.26} = 0.57.$

APPENDIX III.

DIAGRAMS FOR STRESS STRAIN TESTS ON PRECEDING LOG SHEETS.

(When filed, diagrams should be clipped to log sheets.)

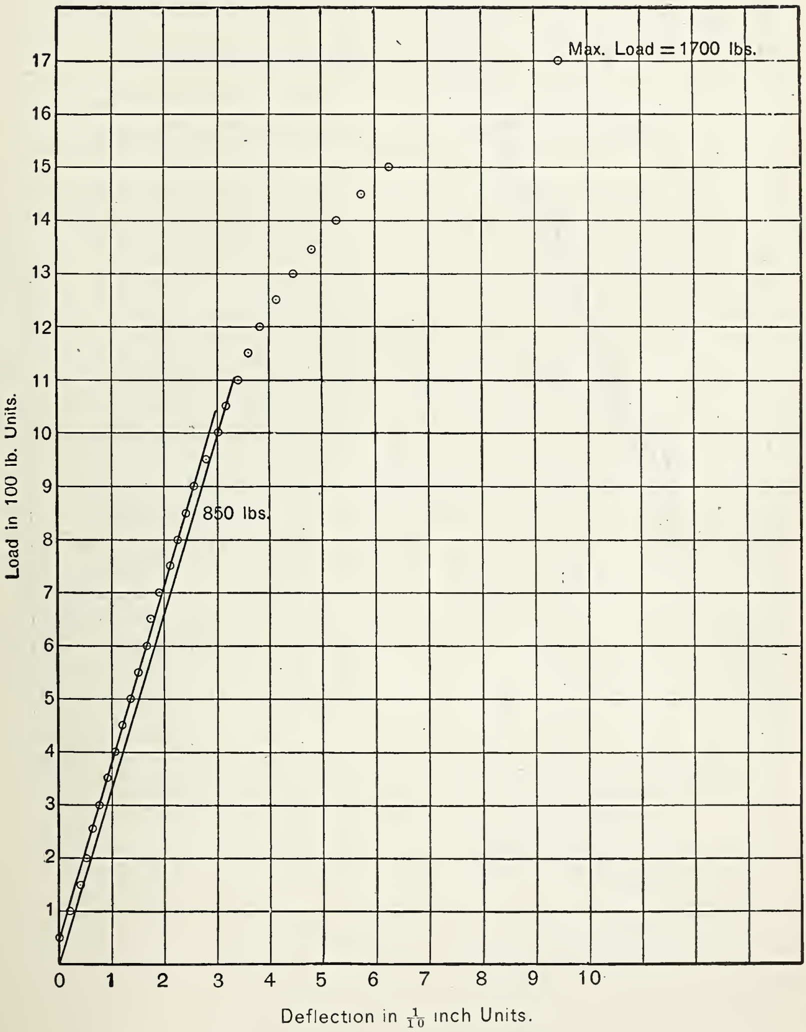


FIG. 1.—Static bending. 109-102-1043. D-4.

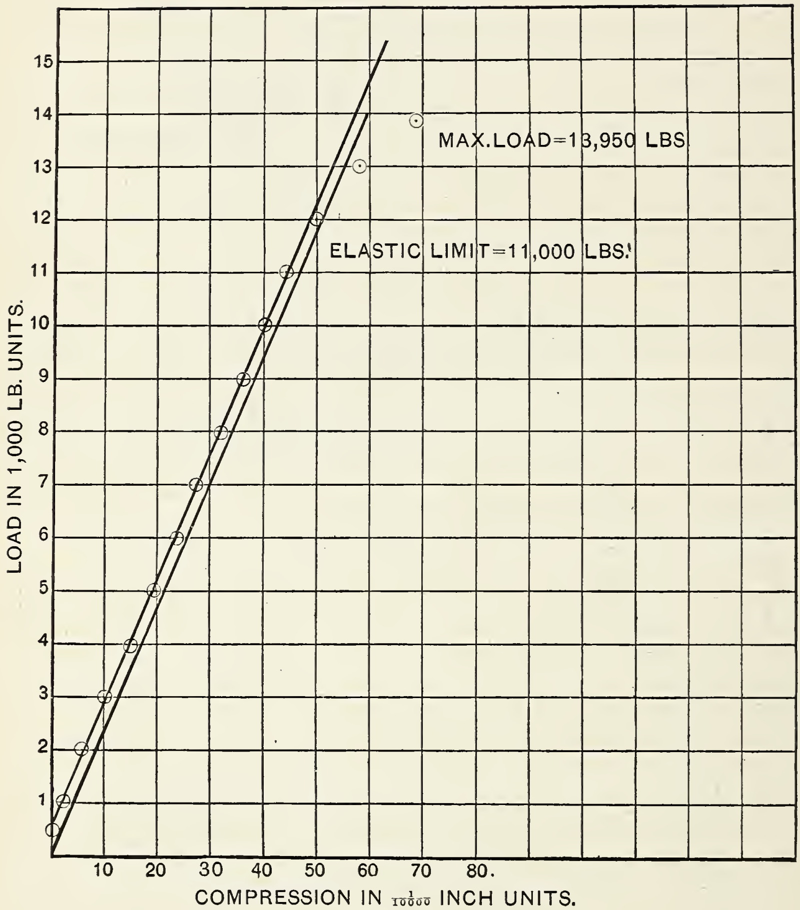


Fig. 2.—Static compression parallel to grain. 104-95-969. A-7.

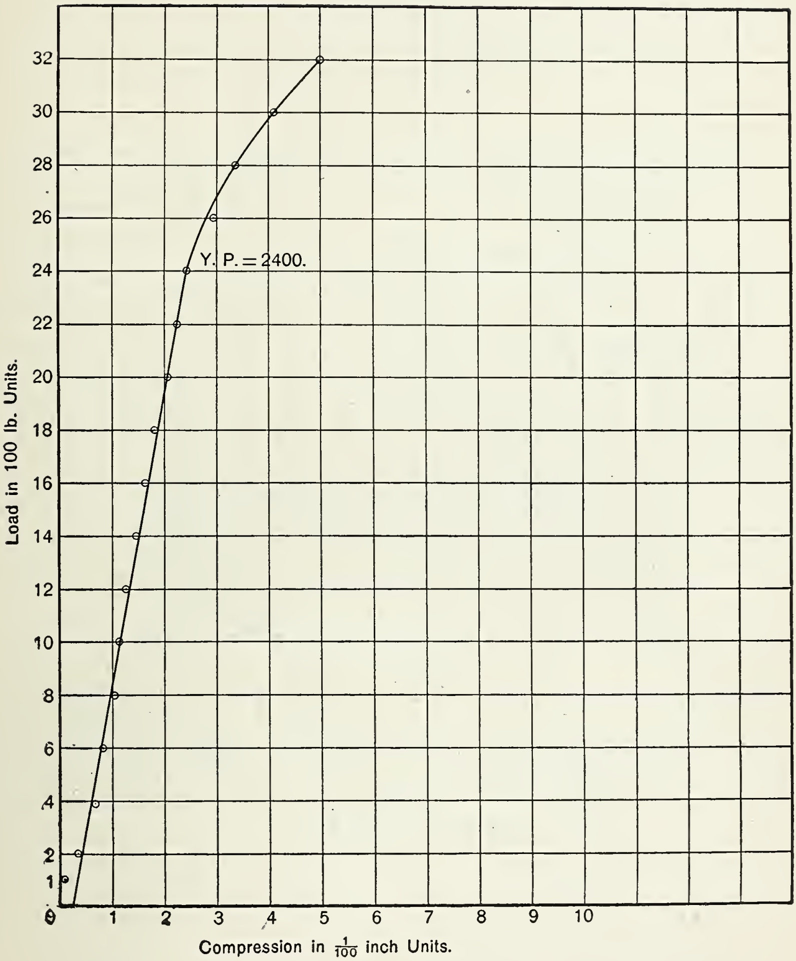


FIG. 3.—Static compression, at right angles to grain. 109 - 102 - 1043. D - 4.

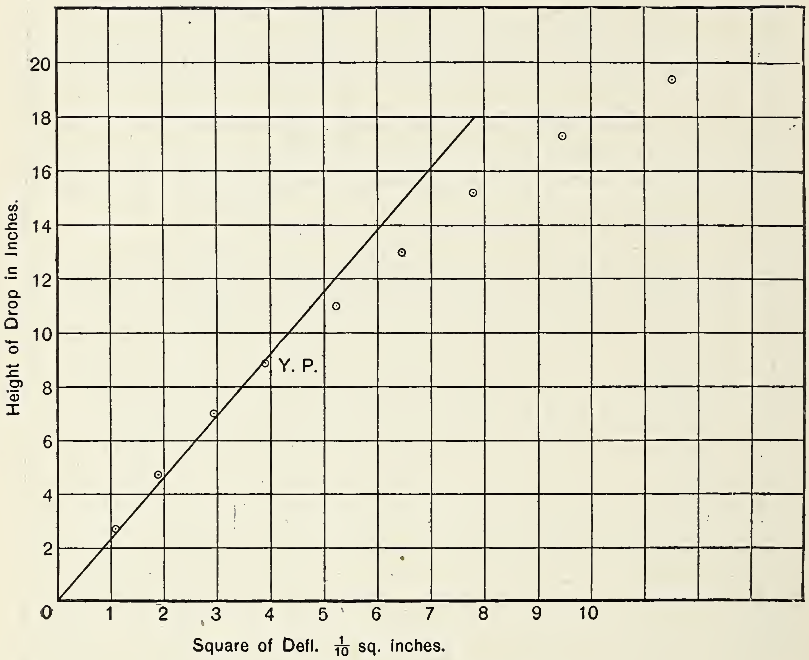


FIG. 4.—Impact bending. 109-102-1043. D-1.

APPENDIX IV.

VARIOUS FORMULAS USED IN COMPUTATIONS INCIDENT TO TIMBER TESTS.

FORMULAS FOR SLIDE RULE CALCULATIONS.

Static Bending.

Load applied at center.

$$J=\frac{0.75\times\text{max. load}}{b\times h}$$

$$M.\,R.=\frac{J\times 2\,l}{h}$$

$$E.\,L.=\frac{M.\,R.\times\text{load at }E.\,L.}{\text{Max. load}}$$

$$E=\frac{E.\,L.\times l^2}{6\times\triangle\times h}$$

$$M.\,Ri.=\frac{\text{Load at }E.\,L.\times\triangle}{l\times b\times h\times 2}$$

$$Sp.\,gr.=\frac{\text{Wet wt.}\times k}{(1+\text{moisture})\times\text{vol. (cu. in.)}}$$

Note on *sp. gr.* $\begin{cases}\text{When wt. is in grams, } k=0.061.\\ \text{When wt. is in pounds, } k=27.7.\end{cases}$

Load applied at third-points.

$$J=\frac{.75\times\text{max. load}}{b\times h}$$

$$M.\,R.=\frac{4\times J\times l}{3\times h}$$

$$E.\,L.=\frac{M.\,R.\times\text{load at }E.\,L.}{\text{Max. load}}$$

$$E=\frac{P\,l^3}{4.7\times\triangle\times b\,h^3}=\frac{E.\,L.\times l^2}{4.7\times\triangle\times h}$$

$$M.\,Ri.=\frac{0.435\times P\times\triangle}{l\times b\times h}$$

$$Sp.\,gr.=\frac{\text{Wet wt.}\times k}{(1+\text{moisture})\times\text{vol. (cu. in.)}}$$

LEGEND.

P = total load on beam at elastic limit, pounds.
J = greatest calculated shear, #/□″.
$M.\,R.$ = modulus of rupture, #/□″.
$E.\,L.$ = fiber stress at elastic limit, #/□″.
$M.\,Ri.$ = modulus of resilience, in #/cu. in.
$Sp.\,gr.$ = specific gravity (dry).
E = modulus of elasticity, #/□″.
b = width of beam, inches.
h = height of beam, inches.
l = length of span, inches.
k = constant.
W = weight of hammer, pounds.
H = height of drop plus deflection, inches.
$\triangle$ = total deflection at elastic limit, inches.
Moisture = per cent of moisture ÷ 100.

Impact Bending.

Load applied at center.

$$E.\,L.=\frac{3\times W\times H\times l}{\triangle\times b\times h^2}$$

$$E=\frac{E.\,L.\times l^2}{6\times\triangle\times h}$$

$$M.\,Ri.=\frac{W\,H}{l\times b\times h}$$

$$Sp.\,gr.=\frac{\text{Wet wt.}\times k}{(1+\text{moisture})\times\text{vol. (cu. in.)}}$$

LEGEND FOR IMPACT DEDUCTIONS.

Observed quantities.

For any one specimen:

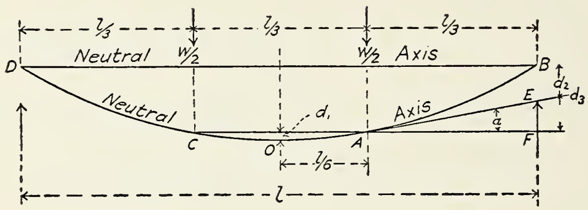
W=weight of hammer in pounds (constant).
s=height of drop in inches (above zero line).
d=deflection at elastic limit in inches (below zero line).
l=length of span in inches=(constant).
h=height of beam in inches=(constant).
b=width of beam in inches=(constant).

d'=deflection caused by static load W.
$\triangle=(d+d')$
$H=(s+d)$

Computed quantities.

$E.\ L.$=Fiber stress at elastic limit	pounds per sq. inch.
E=modulus of elasticity,	" " " "
$M.\ Ri.$=modulus of resilience,	" " cu. "

DEDUCTION OF MODULUS OF ELASTICITY FROM THIRD-POINT LOADING.



$\triangle$ = deflection of beam at center = $d_1+d_2+d_3$.

Solving for d_1.

$$E\,I\frac{d^2y}{dx^2}=M=\frac{W}{2}\times\frac{l}{3}\quad\ldots\ldots\ldots\ (1)$$

Taking origin at O.

$$E\,I\frac{dy}{dx}=\frac{Wlx}{6}+(C=O)\quad\ldots\ldots\ (2)$$

$$E\,I\,y=\frac{Wlx^2}{12}+(C^1=O)\quad\ldots\ldots\ (3)$$

Letting $y=d_1\ x=\frac{l}{6}$.

$$E\,I\,d_1=\frac{Wl^3}{12\times 36}\quad\ldots\ldots\ldots\ (4)$$

$$d_1=\frac{1}{432}\,\frac{Wl^3}{E\,I}\quad\ldots\ldots\ldots\ (5)$$

Solving for d_2.

Formula for cantilever.

$$d_2=\frac{1}{3}\,\frac{PL^3}{EI}$$ AE is drawn tangent to elastic curve at A.

$$P=\frac{W}{2},\ L=\frac{l}{3}$$

$$d_2=\frac{1}{162}\,\frac{Wl^3}{EI}\quad\ldots\ldots\ldots\ (6)$$

Solving for d_3.

From (2) $x=\frac{l}{6}$.

$$E\,I\frac{dy}{dx}=\frac{Wl^2}{36}$$

$$\frac{dy}{dx}=\frac{Wl^2}{36\ EI}=\text{tangent }\alpha\text{ at }A=\frac{d_3}{\frac{l}{3}}$$

$$d_3=\frac{Wl^3}{3\times 36\times EI}=\frac{1}{108}\cdot\frac{Wl^3}{EI}.\quad\ldots\ (7)$$

Solving for $\triangle$.

$$\triangle=d_1+d_2+d_3$$
$$=\left(\frac{1}{432}+\frac{1}{162}+\frac{1}{108}\right)\frac{Wl^3}{EI}$$
$$=\frac{23}{108}\,\frac{Wl^3}{Ebh^3}\quad\ldots\ldots\ldots\ (8)$$
$$E=\frac{Wl^3}{4.7\,\triangle\,bh^3}$$

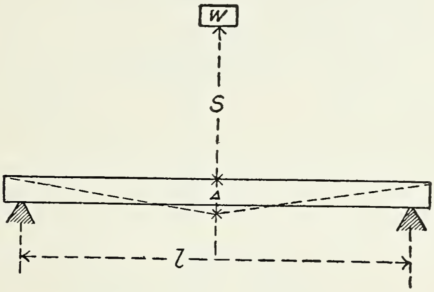
LEGEND.

M = Bending moment in inch-pounds.
W = Load on beam in pounds.
E = Modulus of elasticity.
I = Moment of inertia.

l = Length of span in inches.
b = Width of beam in inches.
h = Height of beam in inches.
$\triangle$ = Total deflection of beam in inches.

Deduction of Formulas for Impact Bending.

Load applied at center.



For any drop below the yield point.

$$W(s+d)=P\frac{(d+d')}{2} \quad \ldots \quad (1)$$

Substituting value of $P=\frac{\triangle\times 48\times EI}{l^3}$,

$$W(s+d)=\frac{24EI\triangle^2}{l^3} \quad \ldots \quad (2)$$

Fiber stress at elastic limit.

Substituting value of P for rectangular beams $=\frac{2\times E.\ L\times bh^2}{3l}$,

$$\text{(1) becomes } WH=\frac{2\times E.\ L.\times bh^2\triangle}{3\times 2\times l} \quad (3)$$

$$E.\ L.=\frac{3\times W\times H\times l}{bh^2\triangle} \quad \ldots \quad (4)$$

For legend, see page 46.

Modulus of elasticity.

Substituting value of P for rectangular beams from the formula for a beam loaded at center $\triangle=\frac{1}{48}\frac{Pl^3}{EI}$

$$\text{(1) becomes } WH=\frac{2\triangle^2 Ebh^3}{l^3} \quad . \quad (5)$$

$$E=\frac{WHl^3}{2\triangle^2 bh^3} \quad \ldots \quad (6)$$

In terms of $E.\ L.$

$$E=\frac{E.L.\times l^2}{6h\triangle} \quad \ldots \quad (7)$$

Modulus of resilience.

$$M.\ Ri=\frac{WH}{lbh} \quad \ldots \quad (8)$$

For determining the yield point plot H against $\triangle^2$. The yield point is that point where the height of drop ceases to be proportional to the square of the deflection.

METHOD OF DETERMINING EFFECT OF SAW IN DRYING DISKS.

The moisture is determined by drying thin disks, cut through the entire section of the beam and tested in a way similar to the disk method (no account is taken of the volatile oils, however). In order to eliminate the drying effect of the power saw used in cutting the disks, several disks may be cut of different thicknesses. Two disks are sufficient for the determination.

The disks are weighed as soon as they are cut. They are then dried at 100° C. until no further appreciable loss in weight is obtained, and the final weight taken.

It may be assumed that the moisture removed from each disk by the saw is equal in each set of disks—all conditions being equivalent. Two equations may then be formed with the percentage of moisture and the loss due to the saw as unknowns. Thus,

$$by=(a+x)-b$$
$$dy=(c+x)-d$$

in which

a=weight of larger disk before drying.
b=weight of larger disk after drying.
c=weight of smaller disk before drying.
d=weight of smaller disk after drying.
x=weight of the moisture removed by the saw.
y=percentage of moisture (and volatile oils) with respect to the dry weight of the timber.

Whence

$$y=\frac{(a-b)-(c-d)}{b-d}$$

$$x=\frac{ad-bc}{b-d}$$

APPENDIX V.

DIAGRAMS OF MACHINES, MATERIALS, AND RECORDS IN TIMBER TEST WORK.

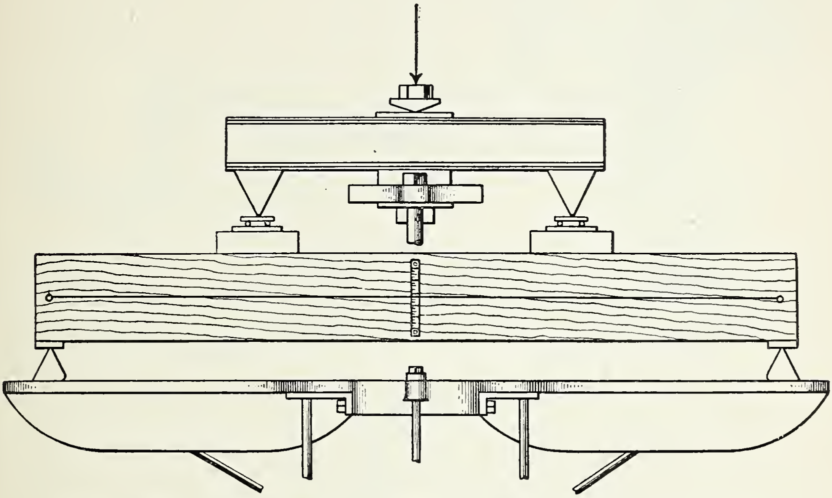


Fig. 1.—Method of testing large beams under static loading at third-points of the span.

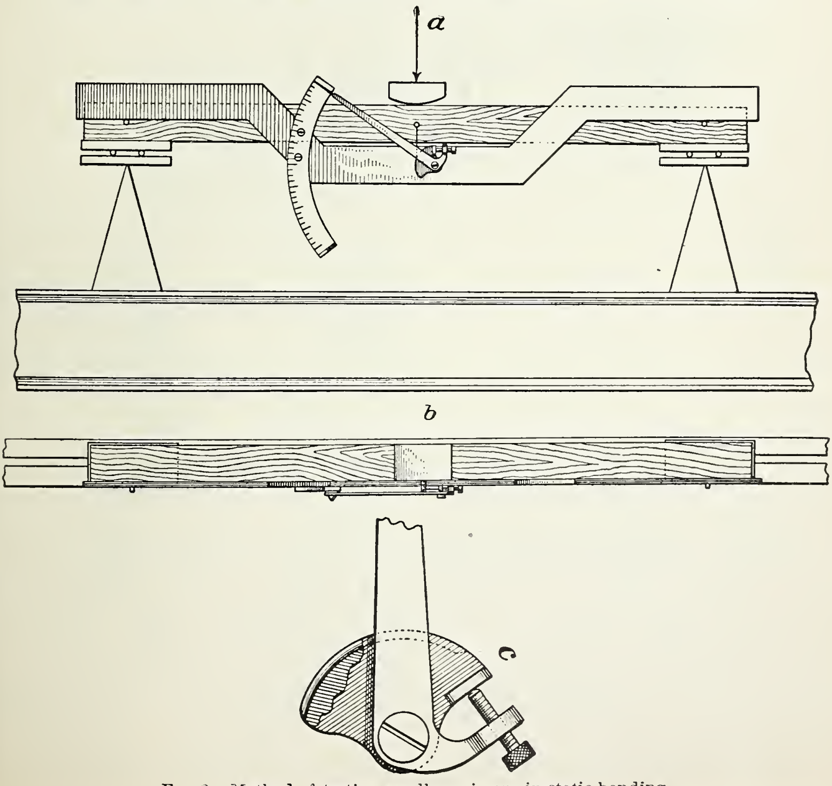


Fig. 2.—Method of testing small specimens in static bending.

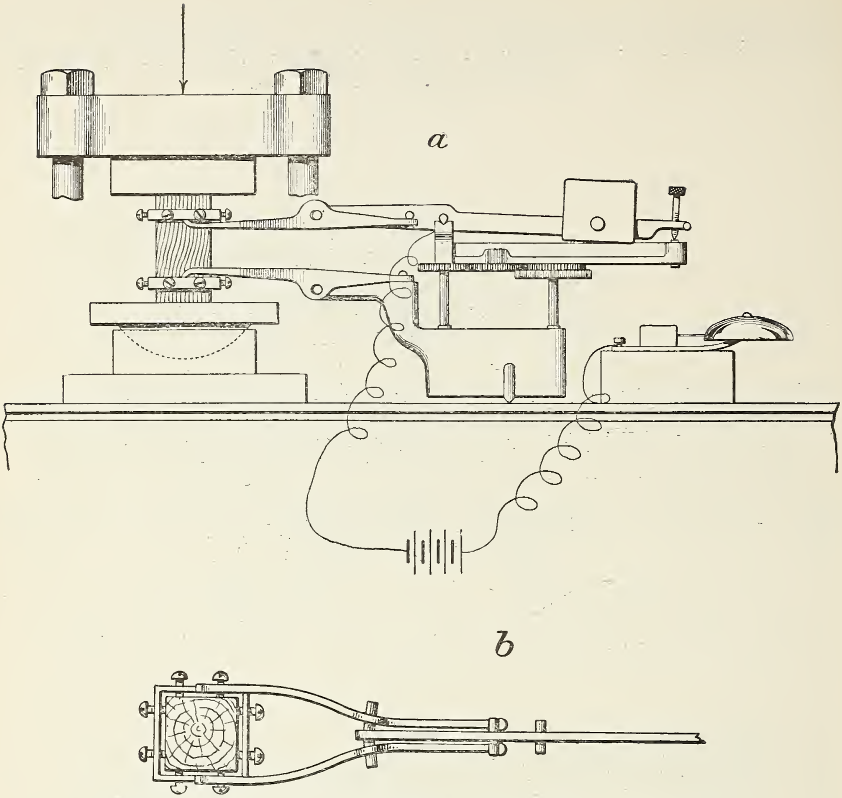


FIG. 3.—Method of testing small specimens in compression parallel to grain.

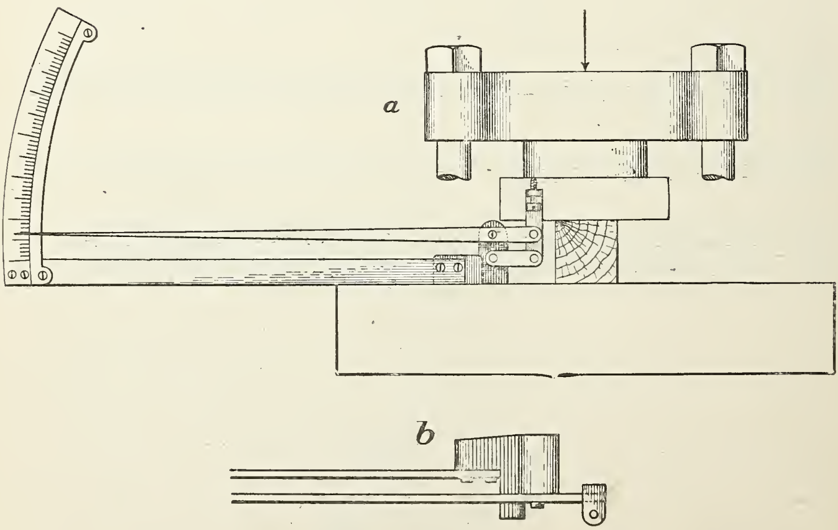


FIG. 4.—Method of testing small specimens in compression at right angles to grain.

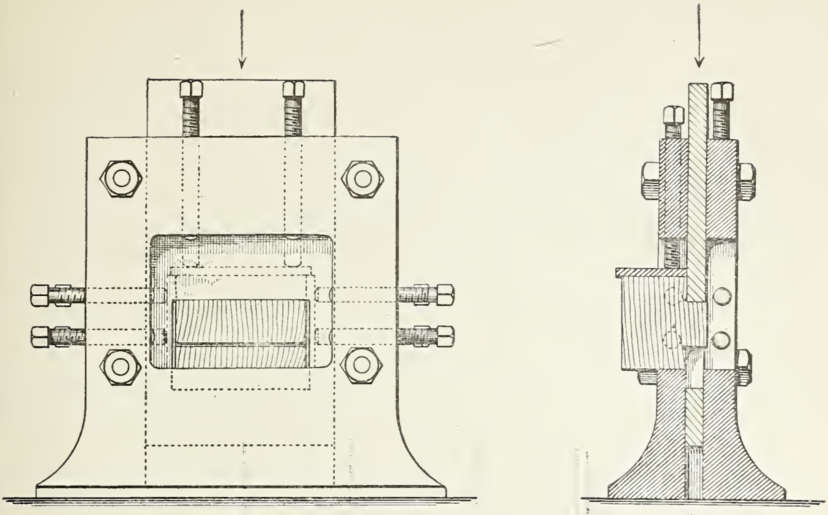


FIG. 5.—Specimens and tool used in shearing tests, both radial and tangential to grain.

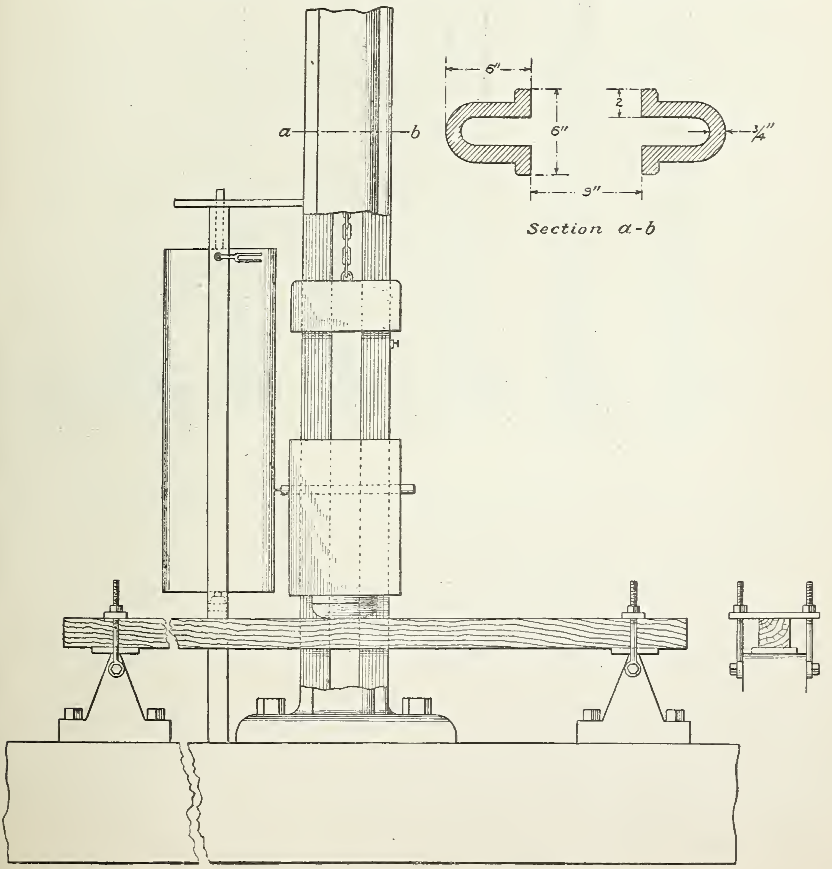


FIG. 6.—Method of test in impact bending.

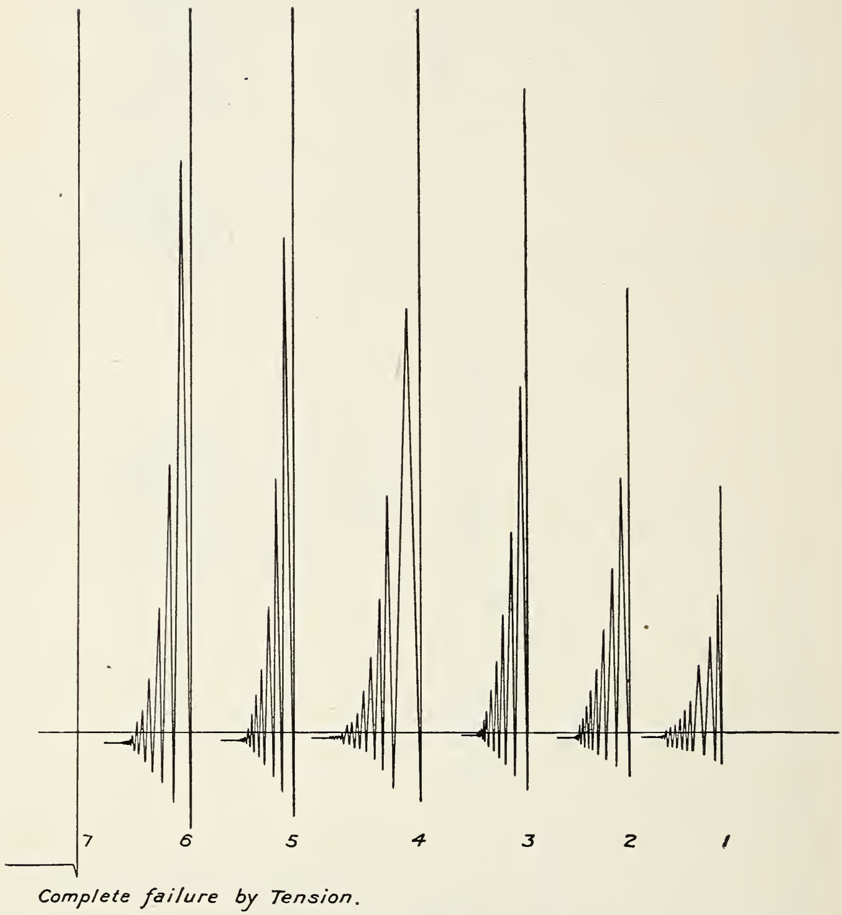


Fig. 6*a*.—Record of impact bending test.

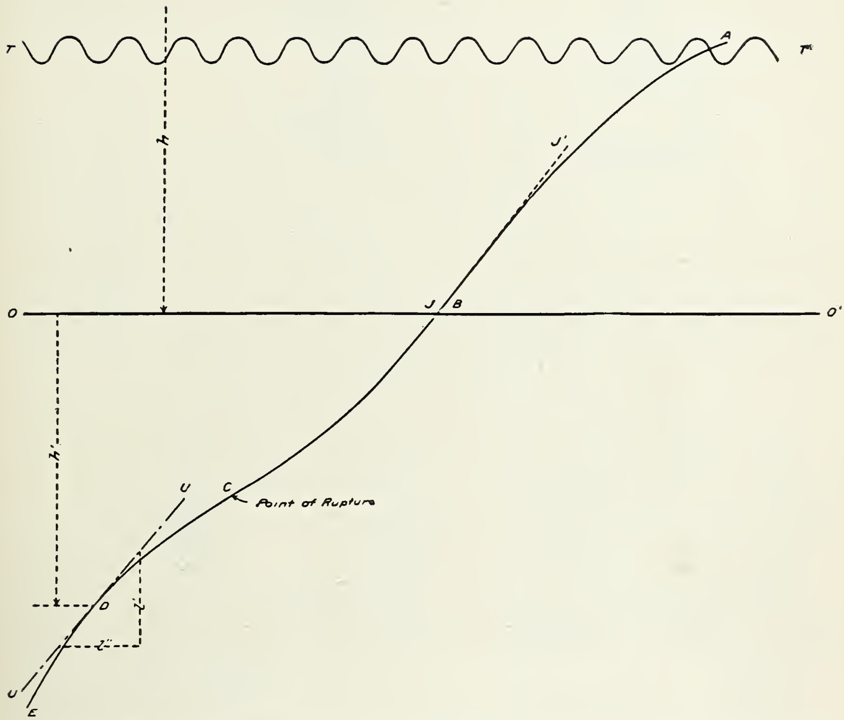


FIG. 6b.—Record of impact test. Specimen ruptured under single blow. *T-T*, tuning-fork record, *O-O'*, datum line.

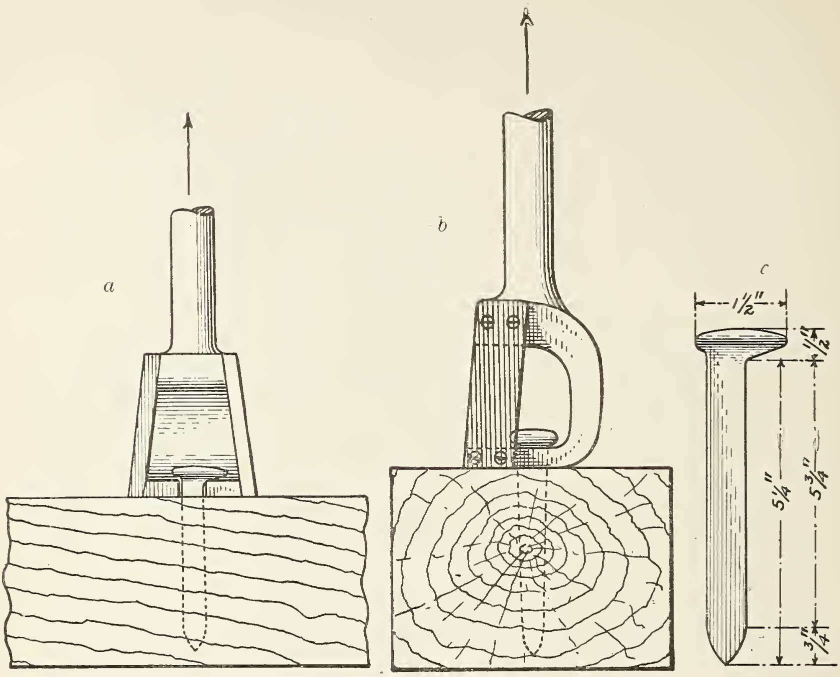


FIG. 7.—Method of spike-pulling tests.

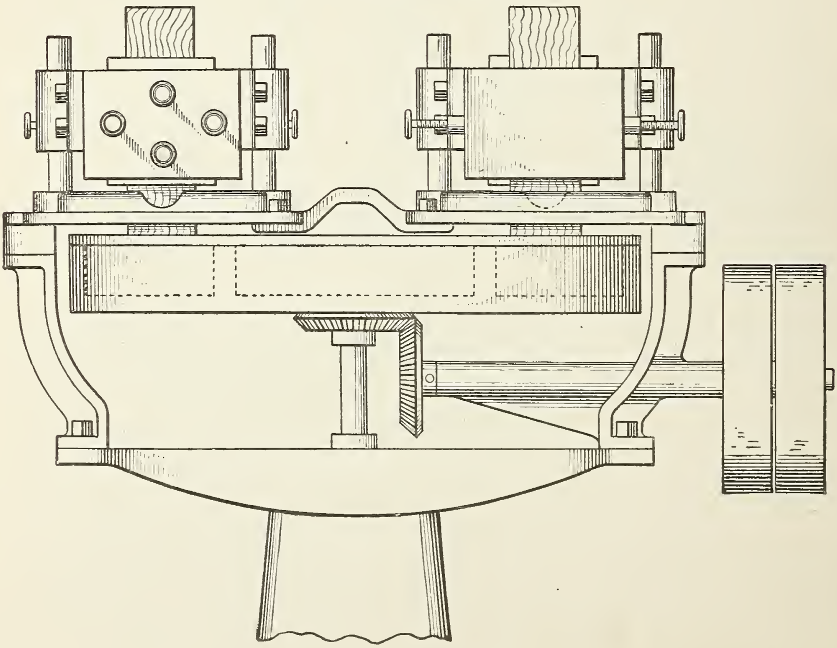


FIG. 8.—Abrasion test.

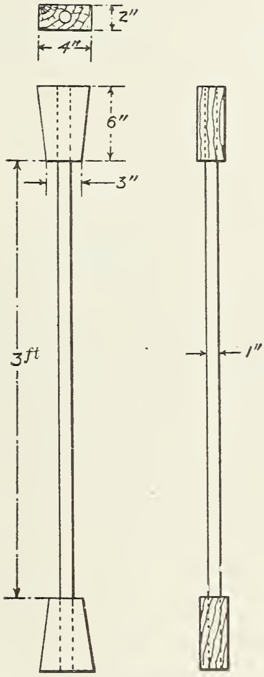


FIG. 9.—Specimens and holders for tension tests.

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